Physiological Protection Against Chemical and Biological Agents

Jonathan W. Kaufman, Ph.D.
Naval Air Warfare Center Aircraft Division
Patuxent River, Maryland

Problem

Chemical/Biological Warfare

- Weapon of mass destruction (strategic)
- Incapacitate or kill enemy forces (tactical)
- Reduce operational effectiveness
- Deprive enemy access to territory, equipment
- Crop, farm animal destruction
- Terrorism

Goal

Developing convenient, reliable individual protection against toxic chemical and biological agents targeting personnel

CW/BW Agent Physical Properties

Deployable Physical States

- Vapor
- Aerosols
  - Neat
  - Thickened
- Dry Powders
  - "dust"
  - microencapsulation

CW/BW Agent Physical Properties

- **Thickening**
  - Controls particle size by slowing evaporation and increasing resistance to shear forces
  - Reduces rates of droplet spread & surface penetration (esp. important for percutaneous transport)
  - Makes decontamination more difficult
- **Dust/Microencapsulation**
  - Enhance agent airway transport by carrier material
  - Reduces environmental degradation of agent

JON - INCLUDE DEFINITION/ DESCRIPTION of NEAT? I'VE DEFINED ALL OTHER STATES.

Factors affecting CW/BW agent effectiveness

- Atmospheric Conditions
- Agent Physiochemical Properties
- Biological Factors

Factors affecting CW/BW agent effectiveness

Atmospheric Conditions

- temperature
- humidity
- wind
- sunlight
- UV strength
- precipitation

Factors affecting CW/BW agent effectiveness

Agent Physiochemical Properties

- Chemical Composition
- Reactivity
- Concentration
- Water/Lipid Solubility
- *Particulates*
  - Aerodynamic Diameter
  - Size distribution
  - shape
  - surface area

REACTIVITY - COULD MEAN A FEW DIFFERENT THINGS - MIGHT WANT TO INCLUDE A SUB-BULLET OR TWO SIMILAR TO 'PARTICULATES'

Chemical Agent Physical Properties

- **Nerve** [*sarin* (GB), *soman* (GD), *V-agents*] - liquid/thickened, highly volatile (exc. V-agents)
- **Blister** [*mustard* (H/HD), *Lewisite* (L)] - liquid/thickened/solid, generally volatile
- **Choking** [*phosgene* (CG)] - liquid, highly volatile
- **Blood** [*hydrogen cyanide* (AC)] - liquid, extremely volatile
- **Psychoactive** [*2-quinuclidinyl benzilate* (BZ)] - liquid, slight volatility

Factors affecting CW/BW agent effectiveness

Biological Properties

- Absorption Pathway
- Physiological State (age, weight, exposed surface area, etc.)
- Health
- Physiological neutralization
- Contact Time

Factors determining BW agent effectiveness

- Small aerosol dose produces infection/intoxication
- Infection or intoxication causes incapacitation or death
- Agent produced easily & cheaply in significant quantities
- Agent stable when dispersed
- Symptoms difficult to detect and treat
- Real-time detection unavailable

JON - MINOR POINT - FONT/POINT SIZE SEEMS SMALLER THAN TEXT ON OTHER CHARTS

Biological Agent Physical Properties

Potential Bacterial Agents

- **Anthrax***
- **Plague***
- **Tularemia***
- **Brucellosis***

* - Likely militarized agent posing significant threat

Biological Agent Physical Properties

Potential Viral Agents

- Smallpox*
- Venezuelan Equine Encephalitis (VEE)*
- Q fever*
- Ebola
- Marburg virus

* - Likely militarized agent posing significant threat

Biological Agent Physical Properties

Potential Biological Toxin Agents

- Botulinum*
- Ricin*
- Staphylococcal Enterotoxin B (SEB)*
- Aflatoxin
- Tricothecene

* - Likely militarized agent posing significant threat

Site of action, biological toxins

Toxins

- cholera - acts on intestines, incap.
- Botulinum - inhibits ACh
- SEB - paralyzes smooth muscle, incap at μg, kills >
- saxitoxin - nerve ion transp., paralyzing & kills
- tetrodotoxin - muscle ion transp., kills by respir. failure
- aflatoxin - hemorrage, fatal
- ricin

POINT SIZE?

BW dose-response relationship

	Effective human dose	Time to effect/effect
Bacteria		
Plague	~3,000 organisms	1-5 days/ lethal
Anthrax	> 8,000 spores	1-5 days/ lethal
Tularemia	10-100 organisms	1-10 days/ incapac.,
Viruses		
Smallpox	1-10 viral particles	6-12 days/ lethal
VEE	1-10 viral particles	2-5 days/ incapac.
Toxins		
Botulinum	0.0048 mg	< 1-2 days/ lethal
SEB	0.039 mg	1-6 hrs/ incapac.
Saxitoxin	< 0.1 mg	minutes/ lethal

CONSIDER ADDING LINES - MAKES THE GROUPING MORE OBVIOUS

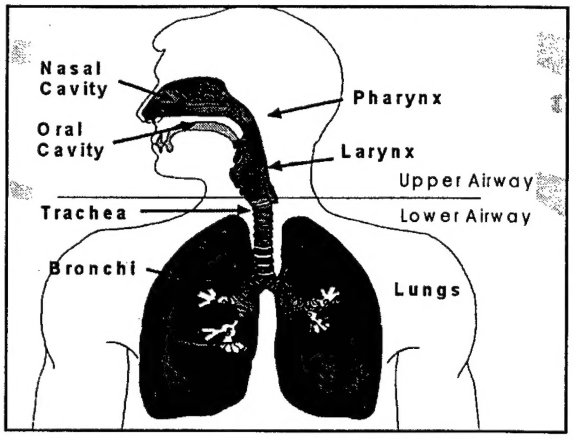
Physiological Pathways

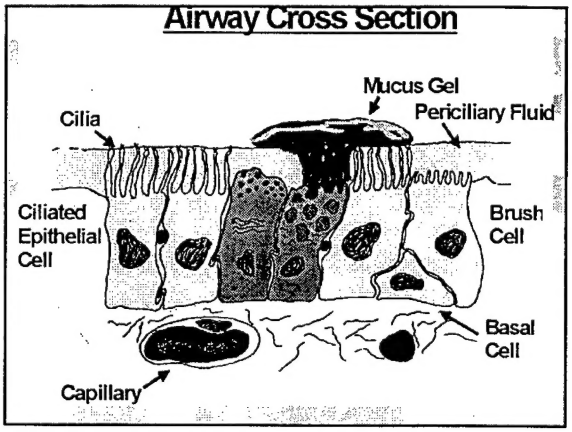
- Respiratory Tract
  - chemical agents
  - bacteria (*anthrax, plague*)
  - viruses (*VEE*)
  - Toxins
- Percutaneous
  - chemical agents
  - bacteria (*tularemia*)
  - viruses (*smallpox*)
- Other pathways (Ocular, Ingestion)

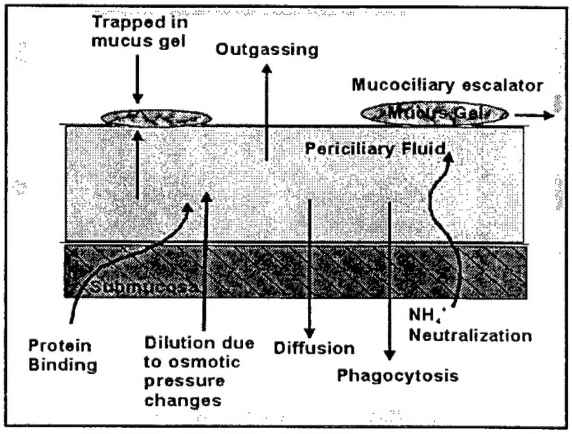
Physiological Pathways

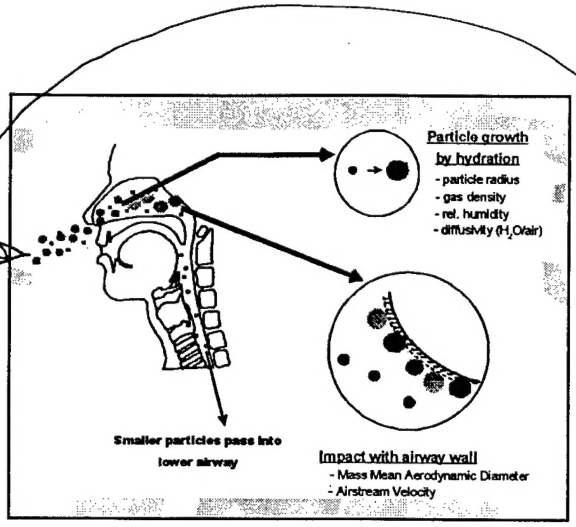
Physiological factors influencing airway deposition and absorption

- breathing frequency
- tidal volume
- minute ventilation
- mucociliary transport
- submucosal blood flow
- metabolism (NH_3 production)

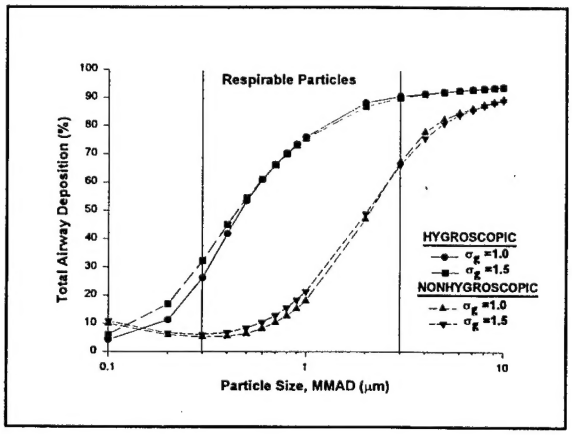

Nasal Cavity
Oral Cavity
Pharynx
Larynx
Upper Airway
Lower Airway
Trachea
Bronchi
Lungs

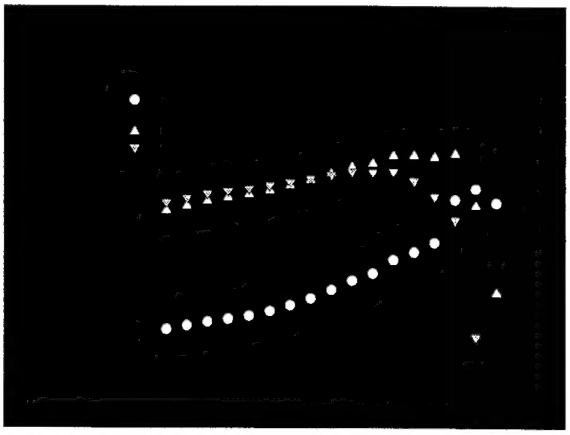

Airway Cross Section
Mucus Gel
Periciliary Fluid
Cilia
Ciliated Epithelial Cell
Brush Cell
Basal Cell
Capillary


Trapped in mucus gel
Outgassing
Mucociliary escalator
Mucus Gel
Periciliary Fluid
Submucosa
Protein Binding
Dilution due to osmotic pressure changes
Diffusion
Phagocytosis
NH4+ Neutralization


Particle growth
by hydration
- particle radius
- gas density
- rel. humidity
- diffusivity (H_2O/air)
Smaller particles pass into
lower airway
Impact with airway wall
- Mass Mean Aerodynamic Diameter
- Airstream Velocity

AHH - CHOO

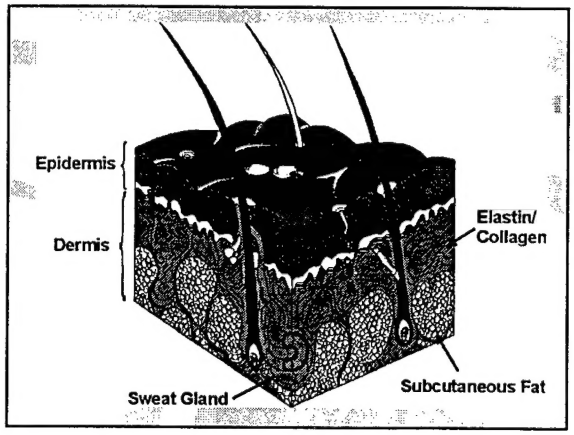

Respirable Particles
Total Airway Deposition (%)
Particle Size, MMAD (μm)
HYGROSCOPIC
σ_g =1.0
σ_g =1.5
NONHYGROSCOPIC
σ_g =1.0
σ_g =1.5



Physiological Pathways

Physiological factors influencing percutaneous absorption

- **Exposed surface area**
- **skin integrity** *(open wounds, lesions)*
- **skin thickness** *(subcutaneous fat)*
- **surface moisture (sweat)**
- **subdurmal blood flow**
- **agent transport mechanisms** *(diffusion, active transport, facilitated diffusion)*



Future Issues

- What new agents are being developed?
- What are potential new delivery methods?
- Can new agents or modified "classical" agents defeat protective measures?
  (equipment, materials, detectors, medical treatments)
- What new protective techniques will work against burgeoning threat?

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
	Viewgraphs	

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Physiological Protection Against Chemical and Biological Agents	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Dr. Jonathan Kaufman	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Naval Air Warfare Center Aircraft Division 22347 Cedar Point Road, Unit #6 Patuxent River, Maryland 20670-1161	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
Naval Air Systems Command 47123 Buse Road Unit IPT Patuxent River, Maryland 20670-1547	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Dr. Jonathan Kaufman
Unclassified	Unclassified	Unclassified	Unclassified	9	19b. TELEPHONE NUMBER (include area code) (301) 342-8883

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18